TRANSISTOR

STEP STRESS TESTING PROGRAM

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FINAL REPORT
FOR

JANTX 2N2945A

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Prepared
For

GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Marshall Space Flight Center, Alabama 35812

DCA RELIABILITY LABORATORY
SPECIAL PRODUCTS DIVISION
975 BENICIA AVE
SUNNYVALE, CALIFORNIA 94086

DCA
RELIABILITY LABORATORY

FOREWARD

This report is a summary of the work performed on NASA Contract NAS8-31944. The investigation was conducted for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama. The Contracting Officer's Technical Representative is Mr. F. Villella.

The short-term objective of this preliminary study of transistors, diodes, and FETs was to evaluate the reliability of these discrete devices, from different manufacturers, when subjected to power and temperature step stress tests.

The long-term objective is to gain more knowledge of accelerated stress testing for use in future testing of varieties of discrete devices, as well as to determine which type of stress should be applied to a particular type of device or design.

This report is divided as follows: description of tests, figures, tables, and appendix.

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1.0 INTRODUCTION

DCA Reliability Laboratory, under Contract NAS8-31944 for NASA/Marshall Space Flight Center, has compiled data for the purpose of evaluating the effect of power/temperature step stress when applied to a variety of semiconductor devices. This report covers the transistor JANTX2N2945A manufactured by Raytheon and Teledyne.

A total of 48 samples from each manufacturer were divided equally (16 per group) into three groups and submitted to the processes outlined in Table I. In addition, two control units were maintained for verification of the electrical parametric testing.

2.0 TEST REQUIREMENTS

2.1 Electrical

All test samples were subjected to the electrical tests outlined in Table II after the prior power/temperature step stress point. These tests were performed using the the Fairchild Model 600 High-Speed Computer-Controlled Test System. In addition, some bench testing was required on the devices.

2.2 Stress Circuit

The test circuit in Figure 1 was used to power all of the test devices during the power/temperature stress conditions. The V_{CE} was varied so that at least one of the devices was subjected to maximum rated power (MRP). All the remaining devices were subjected to no less than 90 percent of MRP. See Figure 1 for load resistance values and voltages.

2.3 Group I - Power Stress

Thirty-two units, 16 from each manufacturer, were submitted to the power stress process. The transistors were stressed in 500-hour steps at 50, 100, 125, 150 and 175 percent MRP for a total of 2500 hours or until 50 percent or more of the devices in a sample lot failed*. Electrical measurements were performed on all specified electrical parameters after each power step. See Table I.

2.4 Group II - Temperature Stress I

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress I process. Group II was subjected to a total of 1600 hours of stress at MRP in increments of 160 hours. The temperature was increased in steps of +25°C, commencing at +75°C and terminating at +300°C or until 50 percent or more of the devices in a sample lot failed*. Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table I.

2.5 Group III - Temperature Stress II

Thirty units, 16 from Teledyne and 14 from Raytheon, were submitted to the Temperature Stress II process. Group III was subjected to a total of 112 hours of stress at MRP in increments of 16 hours. The temperature was increased in steps of +25°C, commencing at +150°C and terminating at +300°C or until 50 percent or more of the devices in a sample lot failed*. Electrical measurements were

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*Conditions for failure:

A) Open or short
B) Leakage exceeds the MIL limit by 100 times
C) Other parameters exceed MIL limits by 50 percent or more

performed on all specified electrical parameters after each temperature step. See Table I.

3.0 DISCUSSION OF TEST RESULTS

3.1 Group I – Power Stress

3.1.1 Raytheon. The Raytheon sample lot completed the entire 2500-hour Group I testing with no catastrophic failures. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 12.5pA from an initial mean of 69.37pA to a final mean of 56.87pA.

2) The mean value for h_{FE} changed 8.3 from an initial mean of 155.6 to a final mean of 147.3.

The control units for this sample lot remained constant throughout the entire Group I testing.

3.1.2 Teledyne. The Teledyne sample lot completed the entire 2500-hour Group I testing with no catastrophic failures. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 69.26pA from an initial mean of 153.5pA to a final mean of 84.24pA.

2) The mean value for h_{FE} changed 69.26 from an initial mean of 153.5 to a final mean of 84.24.

The control units for this sample lot remained constant throughout the entire Group I testing.

3.1.3 Statistical Summary – Group I. Table IV outlines the results of Group I – Power Stress process for the two electrical parameters and measurement points for both Raytheon and Teledyne.

3.2 Group II – Temperature Stress I

3.2.1 Raytheon. The Raytheon sample lot completed a total of 1440 hours before the lot was stopped because of a failure rate that reached 50 percent of the lot. The first failure occurred 160 hours into the +250°C temperature step. Serial Number 4432 failed the minimum h_{FE} limit. The last seven failures occurred 160 hours into the +275°C temperature step. Serial Numbers 4423, 4424, 4426, 4431, 4436, 4437 and 4438 failed the minimum h_{FE} limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 362.25pA from an initial mean of 73.75pA to a final mean of 436.0pA.

2) The mean value for h_{FE} changed 81.43 from an initial mean of 134.9 to a final mean of 53.47.

The control units for this sample lot remained constant throughout the entire Group II testing.

3.2.2 Teledyne. The Teledyne sample lot completed the entire Group II testing with a total of nine catastrophic failures. The first failure occurred 160 hours into the +200°C temperature step. Serial Number 4476 failed the minimum h_{FE} limit. The next failure occurred 160 hours into the +275°C temperature step. Serial Number 4475 failed because of excessive I_{CBO} leakage. The last seven failures occurred 160 hours into the +300°C temperature step. Serial Numbers 4477, 4480, 4482, 4485, 4487, 4488, and 4489 failed because of excessive I_{CBO} leakage. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 551.61nA from an initial mean of 86.87pA to a final mean of 551.7nA.

2) The mean value for h_{FE} changed 12.2 from an initial mean of 159.9 to a final mean of 147.7.

The control units for this sample lot remained constant throughout the entire Group II testing.

3.2.3 Statistical Summary – Group II. Table V of this report outlines the results of Group II – Temperature Stress I testing for the two electrical parameters and all of the measurement points pertaining to both Raytheon and Teledyne.

3.3 GROUP III – Temperature Stress II

3.3.1 Raytheon. The Raytheon sample lot completed the entire 112-hour Group III testing with a total of one catastrophic failure. Two failures had occurred before the actual step stress started. Serial Numbers 4444 and 4445 failed the minimum h_{FE} limit. The one testing failure occurred 16 hours into the +300°C temperature step. Serial Number 4449 failed the minimum h_{FE} limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 13.04pA from an initial mean of 67.33pA to a final mean of 54.29pA.

2) The mean value for h_{FE} changed 45.1 from an initial mean of 160.2 to a final mean of 115.1.

The control units for this sample lot remained constant throughout the entire Group III testing.

3.3.2 Teledyne. The Teledyne sample lot completed the entire 112-hour Group III testing with a total of two catastrophic failures. The two failures occurred 16 hours into the +275°C temperature step. Serial Numbers 5682 and 5692 failed because of excessive I_{CBO} leakage.

Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 367.61pA from an initial mean of 65.29pA to a final mean of 432.9pA.

2) The mean value for h_{FE} changed 15.0 from an initial mean of 146.9 to a final mean of 131.9.

The control units for this sample lot remained constant throughout the entire Group III testing.

3.3.3 Statistical Summary - Group III. Table VI outline results for Group III - Temperature Stress II testing for the two electrical parameters specified for this job. Results are recorded at each measurement point for both Raytheon and Teledyne.

4.0 FINAL DATA SUMMARY

Table VII statistically summarizes the change in the mean value from the zero-hour data to the final data. The graphs of Figures 2 and 4 plot the cumulative percent failures versus the temperature stress level for Group II - Temperature Stress I, and Group III - Temperature Stress II. The graphs of Figures 3 and 5 plot the time step for Group II (160 hours) and Group III (16 hours) versus the temperatures T_1 and T_2 calculated from Figures 2 and 4. Tables VIII and IX summarize the failures encountered for all three stress groups. The failures are separated into two catagories: catastrophic failures in Table VIII and parametric failures in Table IX. The data from Table VIII was used as a source for the graphs in Figures 2 and 4. Figures 2 and 4 were used as a source for the graphs in 3 and 5 respectively. Junction temperature is plotted on an inverse hyperbolic scale.

5.0 CONCLUSIONS

The only Step Stress that was detrimental to both manufacturers' sample lots was the Group II - Temperature Stress I testing. The Raytheon sample lot was stopped 160 hours before the completion of the testing because of half the lot failing h_{FE} limits. Failure Analysis shows that the samples for Raytheon have extensive gold-aluminum intermetalic formations. The absence of shorts, opens, and junction leakage suggests that the loss of h_{FE} was caused by a reduction in emitter effieiency.

The Teledyne samples experienced similar contaminations and, although the lot was not stopped, it ended up having more catastrophic failures than the Raytheon lot. The fact that the reject rate in the Group III testing was slight compared to the Group II testing suggests that time was a factor here. Note that the Group III testing has all the high temperatures as Group II, but the devices in the Group II testing are held at these high temperatures 10 times longer than the Group III devices.

A plot showing cumulative failure distribution for Groups II and III testing was done for both Raytheon and Teledyne (Figures 2 and 3, and 4 and 5, respectively). Figures 2 and 3 display the data for Raytheon used to calculate an activation energy of 2.16eV. Figures 4 and 5 display the data for teledyne used to calculate an activation energy of 2.72eV.

A broken circle around a marked point, on the graph, indicates a freak failure not calculated as part of the regression line. A solid circle around a marked point indicates an isolated failure point. The regression line was drawn using the least square method.

The activation energy was calculated from the formula:

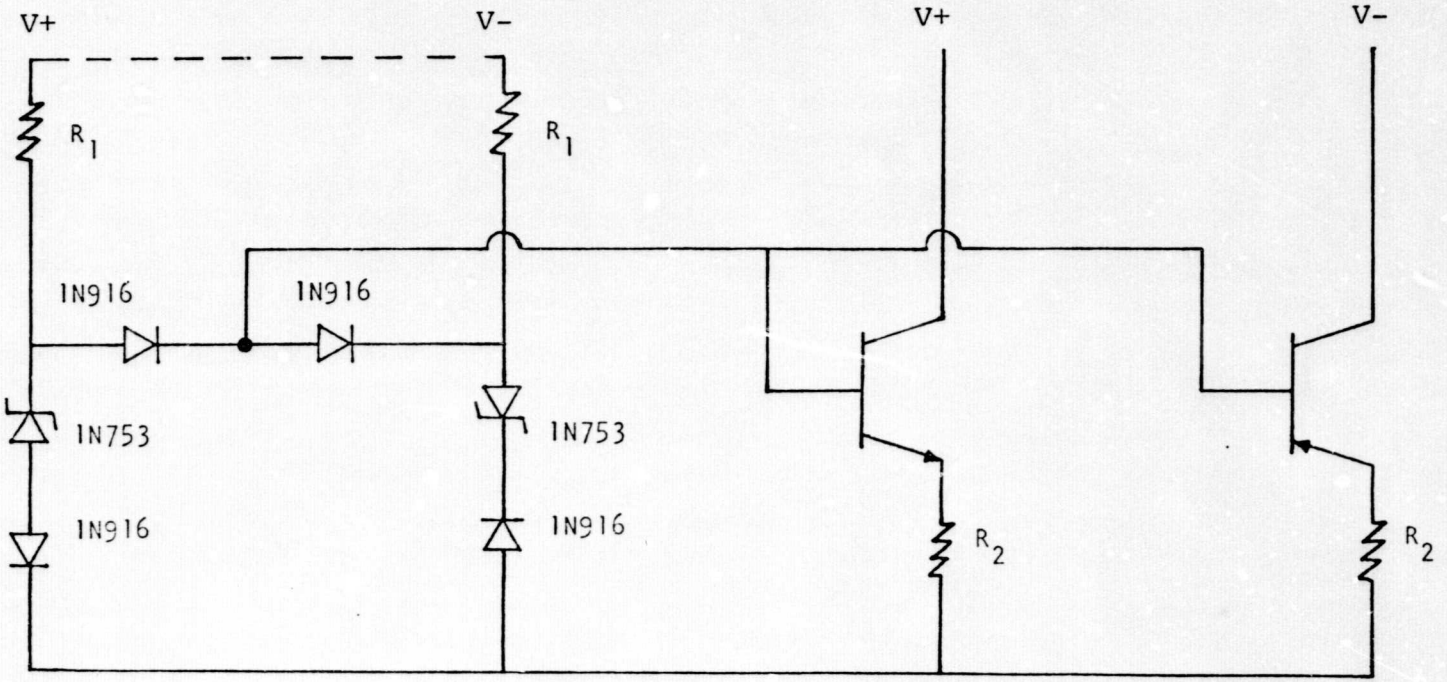
$$E = \left[\ell n \left(\frac{t_1}{t_2} \right) \right] \left[\frac{8.63 \times 10^{-5} \text{ eV/}^{\circ}\text{K}}{\left(\frac{1}{T_1 + 273} \right) - \left(\frac{1}{T_2 + 273} \right)} \right] \text{eV}$$

Where: t_1 = step of Group II - Temp Stress I = 160 hrs.

t_2 = step of Group III - Temp Stress II = 16 hrs.

T_1 = temperature in $^{\circ}$C of 16% failure for Group II.

T_2 = temperature in $^{\circ}$C of 16% failure for Group III.



NOTES: R_1 = 800±5%, 2W. R_2 = 130Ω±1%, ½W

Use V+ for NPN Transistors; Use V- for PNP Transistors.

FIGURE 1

Power/Temperature Stress Circuit

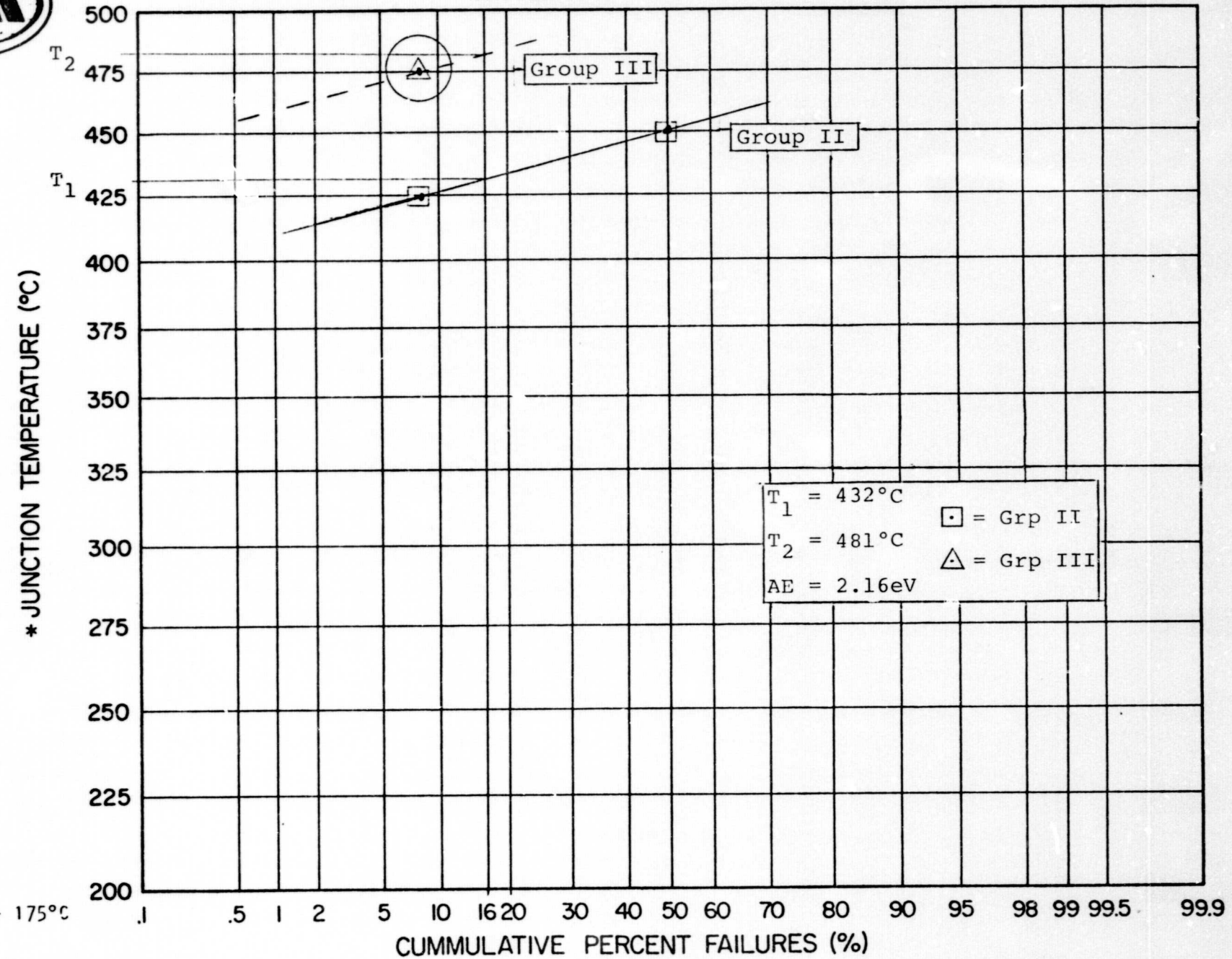
For JANTX2N2945A

NOTE

FOR TABLES

4 THROUGH 7

The minimum/maximum initial and final data generally have an absolute accuracy of ±1% of the reading and ± one digit except for readings greater than 9.99mA which have an absolute accuracy of ±2% of the reading and ± one digit. The data also has a resolution for four digits. The standard deviations, means, delta means, and average means are, therefore, valid indicators of trends over time and temperature, excepting the minor statistical computer error of supplying a constant number of significant digits.

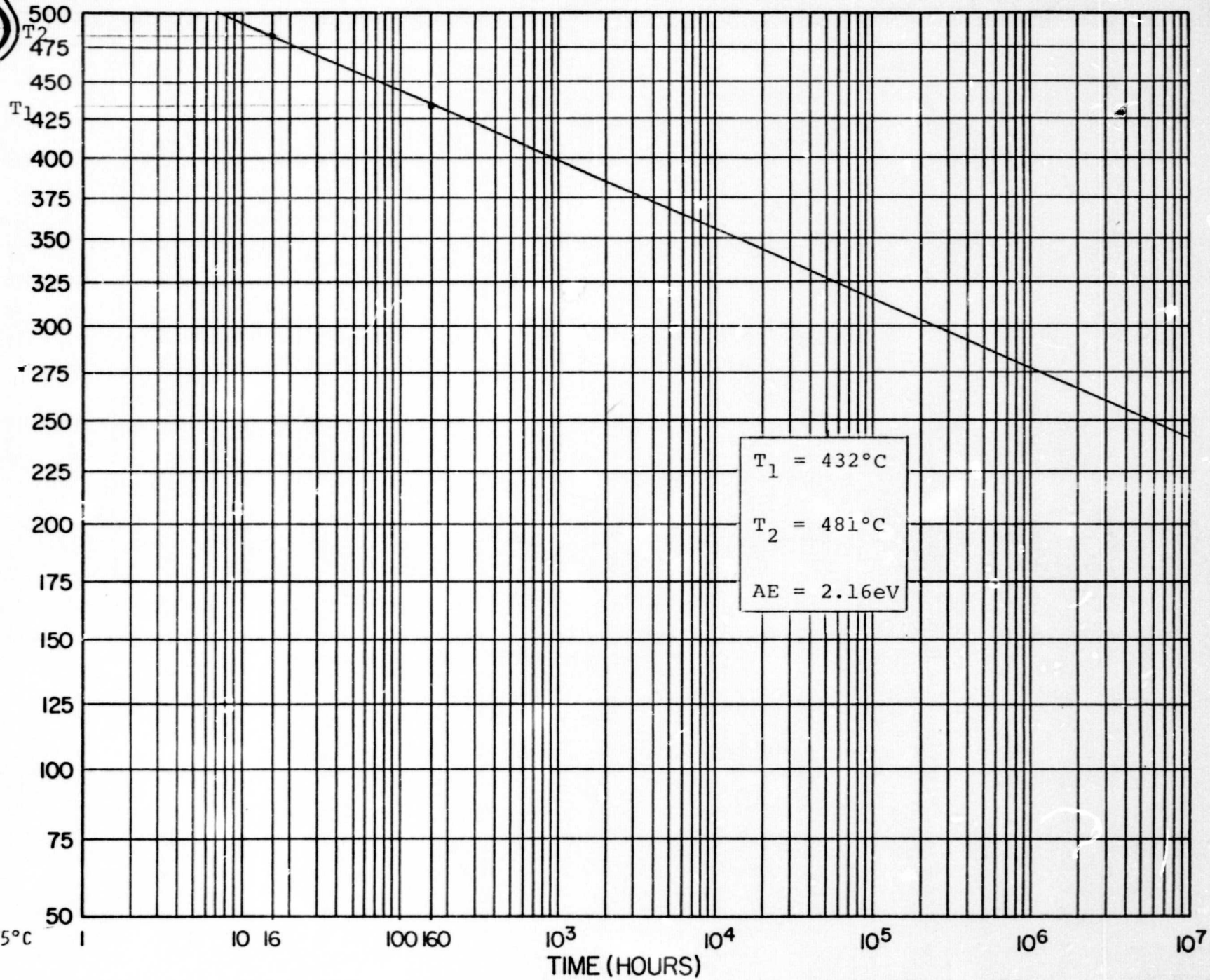


*NOTE

$T_J \simeq T_A + 175°C$

FIGURE 2

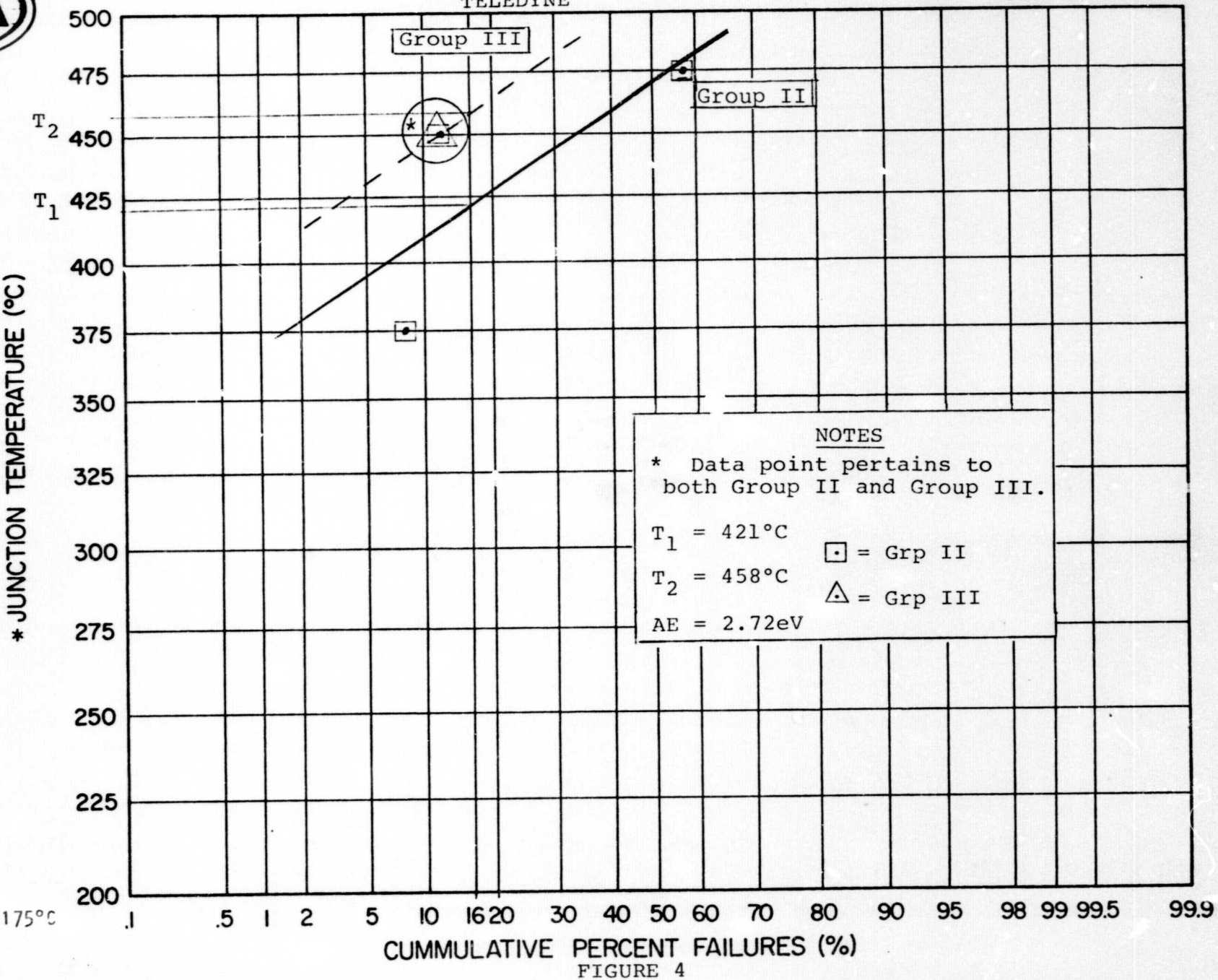
Cumulative Percent Failures Versus Junction Temperature, Raytheon



*NOTE

$T_J \approx T_A + 175°C$

FIGURE 3
Time Steps Versus Junction Temperature, Raytheon

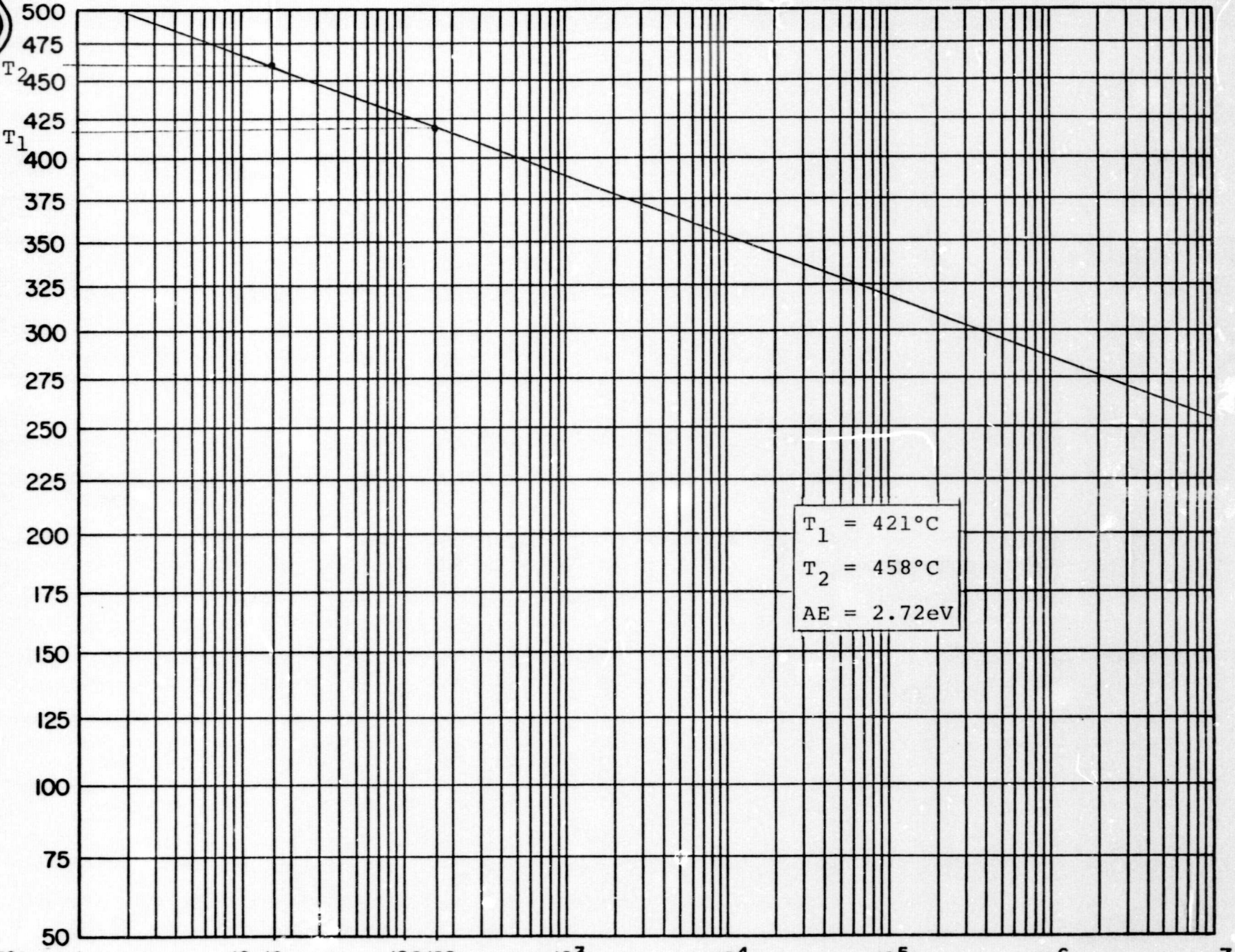


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 4

Cumulative Percent Failures Versus Junction Temperature, Teledyne

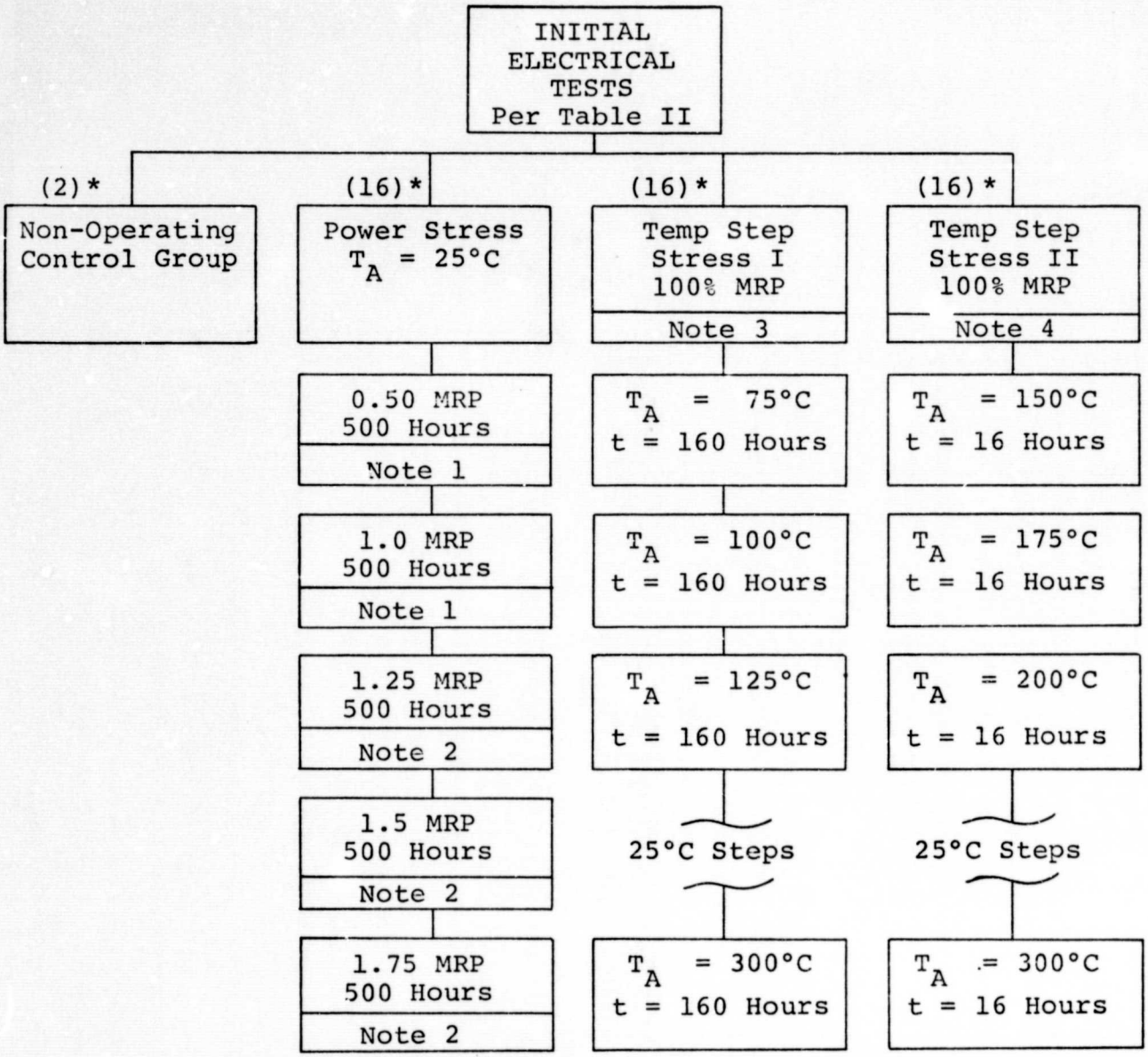


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 5
Time Steps Versus Junction Temperature, Teledyne

TABLE I
TEST FLOW DIAGRAM



*Quantity per manufacturer (Raytheon and Teledyne)

NOTES:

1) Electrical measurements per Table II were made at 50, 150, 250 and 500 hours.
2) Electrical measurements per Table II were made at 10, 25, 50, 150, 250 and 500 hours.
3) Electrical measurements per Table II were made at the end of each 160 hours.
4) Electrical measurements per Table II were made at the end of each 16 hours.

TABLE II
PARAMETER AND TEST CONDITIONS

PARAM-ETER	CONDITIONS	SPECIFICATION LIMIT		CATASTROPHIC[1] LIMIT		UNITS
		MIN	MAX	MIN	MAX	
I_{CBO}	@ V_{CB} = -25V, I_E = 0		-0.2		-20	nA
h_{FE}	@ V_{CE} = -0.5V, I_C = -1mA	70	900	35	1350	—

1. In addition, any open or short shall be considered catastrophic.

TABLE III
POWER STRESS BURN-IN CONDITIONS

I_E = 43.5mA	
V_{CE} =	PERCENT P_D
4.6V	50
9.1V	100
11.4V	125
13.7V	150
16.0V	175

TABLE IV
GROUP I – POWER STRESS DATA SUMMARY

PARAMETER	I_{CBO} = 0.2nA (max)		h_{FE} = 70(min) 900 (max)					
CONDITIONS AND LIMIT	@ V_{CB} = -25V, I_E = 0		@V_{CE}= -0.5V & I_C= -1.0mA					
IDENTIFICATION	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE				
INITIAL DATA								
MIN VALUE	50.00pA	50.00pA	105.00	111.00				
MAX VALUE	100.00pA	140.00pA	223.00	214.00				
MEAN	69.37pA	153.50pA	155.60	153.50				
STD DEV	12.98pA	28.98pA	32.32	28.98				
INTERIM DATA								
POWER 50 TO 125% Δ MEAN VALUE								
50% POWER								
50 hrs	-16.16pA	-0.3pA	-0.9	-0.3				
150 hrs	- 4.37pA	-1.1pA	-1.7	-1.1				
250 hrs	1.25pA	-2.8pA	-3.7	-2.8				
500 hrs	-25.62pA	-2.6pA	-5.3	-2.6				
100% POWER								
550 hrs	-28.75pA	-2.0pA	-1.8	-2.0				
650 hrs	-36.87pA	-4.3pA	-1.0	-4.3				
750 hrs	-30.00pA	-5.0pA	-2.8	-5.0				
1000 hrs	-23.12pA	-8.6pA	-3.7	-8.6				
125% POWER								
1010 hrs	-18.75pA	-10.2pA	-3.7	-10.2				
1025 hrs	- 0.62pA	- 9.2pA	-2.7	- 9.2				
1050 hrs	- 3.75pA	- 9.2pA	-2.5	- 9.2				
1150 hrs	-15.00pA	-13.1pA	-5.4	-13.1				
1250 hrs	-12.50pA	-12.8pA	-2.7	-12.8				
1500 hrs	- 6.87pA	-12.0pA	-0.5	-12.0				

(continued on second sheet)

TABLE IV (Cont'd)

(continued from first sheet) GROUP I – POWER STRESS DATA SUMMARY

PARAMETER	I_{CBO} = -0.2nA		h_{FE}=70(min) 900 (max)					
CONDITIONS AND LIMITS	@ V_{CB} = -25V, I_E=0		@V_{CE}= -0.5V & I_C= -1.0mA					
IDENTIFICATION	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE				
INITIAL DATA								
MIN VALUE	50.00pA	50.00pA	105.00	111.00				
MAX VALUE	100.00pA	140.00pA	223.00	214.00				
MEAN	69.37pA	153.50pA	155.60	153.50				
STD DEV	12.98pA	28.98pA	32.32	28.98				
INTERIM DATA								
POWER 150 TO 175% Δ MEAN VALUE								
150% POWER								
1510 hrs	-15.62pA	-23.40pA	-1.3	-23.40				
1525 hrs	-16.25pA	-25.00pA	0.3	-25.00				
1550 hrs	-15.62pA	-35.80pA	-0.8	-35.80				
1650 hrs	- 5.00pA	-41.20pA	-0.8	-41.20				
1750 hrs	-13.12pA	- 1.10pA	-8.7	- 1.10				
2000 hrs	- 8.12pA	-54.06pA	-3.5	-54.06				
175% POWER								
2010 hrs	-12.50pA	-56.36pA	-3.8	-56.36				
2025 hrs	- 5.00pA	-50.70pA	-5.7	-50.70				
2050 hrs	- 6.25pA	-56.36pA	-3.6	-54.70				
2150 hrs	1.88pA	-54.70pA	-5.9	-59.98				
2250 hrs	- 2.50pA	-58.71pA	-4.6	-58.71				
2500 hrs	-12.50pA	-69.26pA	-8.3	-69.26				
FINAL DATA								
MIN VALUE	0.00pA	10.00pA	98.00	58.20				
MAX VALUE	90.00pA	120.00pA	218.00	107.00				
MEAN	56.87pA	84.24pA	147.30	84.24				
STD DEV	18.61pA	13.51pA	29.02	13.51				

NOTE: Catastrophic Rejects removed from data.

TABLE V

GROUP II. TEMP STRESS I DATA SUMMARY (160 HOUR STEPS)

PARAMETERS	I_{CBO} = 0.2nA (max)		h_{FE} = 70(min) 900(max)					
CONDITIONS AND LIMITS	@ V_{CB} = -25V, I_E = 0		@V_{CE} = -0.5V, I_C = -1.0mA					
IDENTIFICATION	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE				
INITIAL DATA								
MIN VALUE	60.00pA	70.00pA	90.00	110.10				
MAX VALUE	110.00pA	120.00pA	182.70	190.20				
MEAN	73.75pA	86.87pA	134.90	159.90				
STD DEV	11.66pA	17.22pA	25.53	21.09				
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
Total Hrs / Temp(T_A)								
160 / 75°C	-18.13pA	-25.000pA	0.70	- 1.7				
320 / 100°C	-17.50pA	-23.120pA	13.00	5.8				
480 / 125°C	-15.00pA	-30.000pA	15.50	4.0				
640 / 150°C	-15.63pA	-11.870pA	13.30	-11.2				
800 / 175°C	-10.00pA	-11.870pA	6.20	-27.1				
960 / 200°C	-14.38pA	313.130pA	0.80	-34.6				
1120 / 225°C	-18.75pA	-23.120pA	2.50	-32.6				
1280 / 250°C	- 5.63pA	201.830pA	-10.40	-12.8				
1440 / 275°C	362.25pA	10.103nA	-81.43	- 2.3				
1600 / 300°C	JOB STOPPED	551.610nA	JOB STOPPED	-12.2				
				NOTE: CATASTROPHIC REJECTS REMOVED FROM DATA				
FINAL DATA								
FINAL TEMP (T_A)	275°C	300°C	275°C	300°C				
MIN VALUE	10.000pA	60.000pA	12.00	68.00				
MAX VALUE	3.332nA	7.440μA	129.00	191.00				
MEAN	436.000pA	551.700nA	53.47	147.70				
STD DEV	923.700pA	1.843μA	37.58	30.24				

TABLE VI

GROUP III. TEMP STRESS II DATA SUMMARY (16 Hour Steps)

PARAMETERS	I_{CBO} = 0.2nA (max)		h_{FE}=70(min) 900(max)					
CONDITIONS AND LIMITS	@ V_{CB} = -25V, I_E = 0		@V_{CE}= -0.5, I_C= -1.0mA					
IDENTIFICATION	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE				
INITIAL DATA								
MIN VALUE	40.00pA	0.00A	107.00	110.00				
MAX VALUE	110.00pA	100.00pA	223.00	183.00				
MEAN	67.33pA	65.29pA	160.20	146.90				
STD DEV	15.26pA	20.61pA	37.03	17.87				
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
Total Hrs / Temp (T_A)								
16 / 150°C	-10.19pA	-10.00pA	3.2	- 4.5				
32 / 175°C	- 8.76pA	- 9.41pA	2.0	-12.9				
48 / 200°C	-10.90pA	-10.58pA	- 1.9	-27.1				
64 / 225°C	- 0.19pA	- 4.11pA	- 5.3	-22.4				
80 / 250°C	- 5.19pA	- 1.17pA	- 6.3	- 2.0				
96 / 275°C	9.81pA	113.73nA	-13.3	5.7				
112 / 300°C	-13.04pA	367.61pA	-45.1	-15.0				
				NOTE: CATASTROPHIC REJECTS REMOVED FROM DATA				
FINAL DATA								
FINAL TEMP (T_A)	300°C	300°C	300°C	300°C				
MIN VALUE	0.00A	40.000pA	33.00	64.80				
MAX VALUE	110.00pA	4.900nA	197.00	156.00				
MEAN	54.29pA	432.900pA	115.10	131.90				
STD DEV	27.70pA	1.244nA	45.93	23.17				

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TABLE VII
FINAL DATA SUMMARY

PARAMETER	SPECIFICATIONS LIMIT		UNITS	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE					
					POWER STRESS		TEMPERATURE STRESS I		TEMPERATURE STRESS II	
	MIN	MAX			RAYTHEOM	TELEDYNE	RAYTHEON	TELEDYNE	RAYTHEON	TELEDYNE
I_{CBO}	-	0.2	nA		-.01276	-.02384	+.02747	+56.210	-.00549	+16.295
h_{FE}	70	900	-		-3.2731	-23.980	-4.3478	-12.470	-9.5286	-11.171

NOTE: Catastrophic reject(s) removed from data.

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TABLE VIII
STEP STRESS CATASTROPHIC FAILURE SUMMARY

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
100% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
125% 10 hr.	0	–	0	–
15 hr.	0	–	0	–
25 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
150% 10 hr.	0	–	0	–
15 hr.	0	–	0	–
25 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
175% 10 hr.	0	–	0	–
15 hr.	0	–	0	–
25 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	0	–	0	–
100° C	0	–	0	–
125°C	0	–	0	–
150°C	0	–	0	–
175°C	0	–	0	–
200°C	0	–	1	A
225°C	0	–	0	–
250°C	1	A	0	–
275°C	7	A	1	B
300°C	JOB STOPPED		7	B

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	0	–	0	–
175°C	0	–	0	–
200°C	0	–	0	–
225°C	0	–	0	–
250°C	0	–	0	–
275°C	0	–	2	B
300°C	1	A	0	–

MFR A → RAYTHEON

MFR B → TELEDYNE

NOTES:

A) $h_{FE} < 35$

B) $I_{CBO} > 20nA$

TABLE IX
STEP STRESS PARAMETRIC FAILURE SUMMARY

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
100% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
125% 10 hr.	0	–	0	–
15 hr.	0	–	0	–
25 hr.	0	–	1	A
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
150% 10 hr.	0	–	0	–
15 hr.	0	–	0	–
25 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
175% 10 hr.	0	–	0	–
15 hr.	0	–	0	–
25 hr.	0	–	0	–
100 hr.	0	–	1	B
100 hr.	0	–	0	–
250 hr.	0	–	1	B

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	0	–	0	–
100° C	0	–	0	–
125°C	0	–	0	–
150°C	0	–	0	–
175°C	0	–	1	B
200°C	0	–	0	–
225°C	0	–	0	–
250°C	1	B	2 / 1	A / B
275°C	2	B	4	A
300°C	JOB STOPPED		0	–

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	0	–	0	–
175°C	0	–	0	–
200°C	0	–	0	–
225°C	0	–	0	–
250°C	0	–	0	–
275°C	0	–	1 / 1	A / B
300°C	1	B	2	A

MFR A → RAYTHEON

MFR B → TELEDYNE

NOTES:

A) I_{CBO} Maximum Limit Failure

B) h_{FE} Minimum Limit Failure

APPENDIX

FAILURE ANALYSIS

MSFC STEP-STRESS TEST

JANTX2N2945A

FAILURE ANALYSIS- TRANSISTORS

Date 20 September 1978

J/N 2CN242-10B P/N JTX2N2945A (PNP) MFR: Raytheon S/C

FAILURE VERIFICATION: Limit: 25 nA Max. Limit: 35 Min.

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} @ V_{CB} = -25 V.	BV_{EBO} -volts-	h_{FE} @ I_C= 1.0uA; V_{CE} = -0.5 V.	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ.@ test sequence #:	INITIAL REJ. FOR:
4423	54	74	< 1 nA	68	0.16	0.82	MP-10	h_{FE},
4426	42	42	<1 nA	28	0.20	0.82	MP-10	h_{FE} low
4436	92	92	<1 nA	64	2.3	0.82	MP-10	h_{FE} low

INTERNAL VISUAL INSPECTION:

All three Raytheon samples have extensive gold-aluminum intermetallic formation. (See Figure A-1.) The gold wires have alloyed extensively so that their original size and shape are distorted near the die.

CONCLUSIONS:

These samples failed due to catastrophic loss of h_{FE}. The absence of shorts, opens, and junction leakage suggests that the loss of h_{FE} was caused by a reduction in emitter efficiency. This emitter degradation was caused by migration of impurities from the intermetallics which acted to reduce lifetime in the bulk silicon.

*h_{FE} trace present. Cannot meet stated test conditions.
**h_{FE} trace very leaky. H = hysteresis
S = soft D = drift Inv = inversion Uns = unstable R = resistive

MSFC STEP-STRESS TEST

JANTX2N2945A

FAILURE ANALYSIS- TRANSISTORS

Date 20 September 1978

J/N 2CN242-10B P/N JTX2N2945A (PNP) MFR: Teledyne S/C

FAILURE VERIFICATION: Limit: 25 nA Max. Limit: 35 Min.

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} @ V_{CB} = -25 V.	BV_{EBO} -volts-	h_{FE} @ I_C= 1.0 uA; V_{CE} = -0.5 V.	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ.@ test sequence #:	INITIAL REJ. FOR:
4475	35 Inv 1mA	83	454 nA	43	none*	0.82	MP-11	h_{FE} low
4476	R	44	10 nA	44	none R	0.86	MP-6	h_{FE} low
4482	36 Inv 300uA	82	200 nA	42	none*	0.82	MP-10	I_{CBO}

INTERNAL VISUAL INSPECTION:

S/N 4475 and 4482 have no significant visual defects.

S/N 4476 has an extraneous bit of metallization which crosses the channel-stopper between the emitter and collector areas. (See Figure A-3.)

CONCLUSIONS:

Teledyne samples 4475 and 4482 have surface leakage due to contamination, as demonstrated by the inversions seen during the BV_{CEO} and I_{CBO} measurements above. This leakage has degraded the h_{FE}.

S/N 4476 has a collector-emitter short caused by the extraneous bit of metallization on the channel-stopper diffusion. (See Figure A-3.) This was verified by probing between the extraneous metal and the collector or emitter. The metal showed continuity with both structures. This short which may have developed by spot alloying while the die was very hot (See Figure A-3) has destroyed the device function.

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky.)

H = hysteresis

S = soft D = drift Inv = inversion Uns = unstable R = resistive

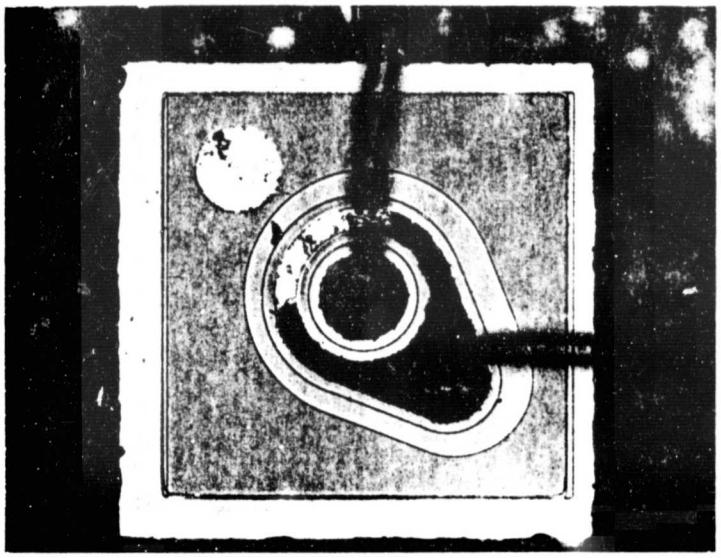

FIGURE A-1
S/N 4426. MAGNIFICATION 136X.
Typical Raytheon die layout. Note the extensive intermetallic formation.

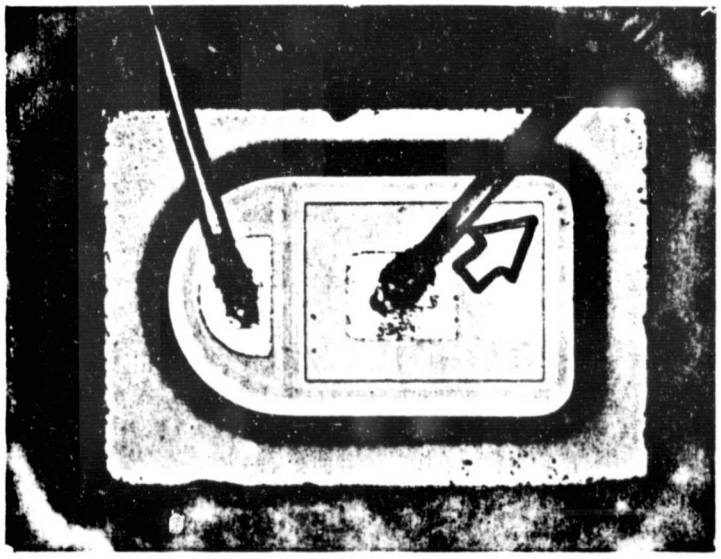

FIGURE A-2
S/N 4476. MAGNIFICATION 136X.
Typical Teledyne die with mesa geometry.
Arrow: See Figure A-3.

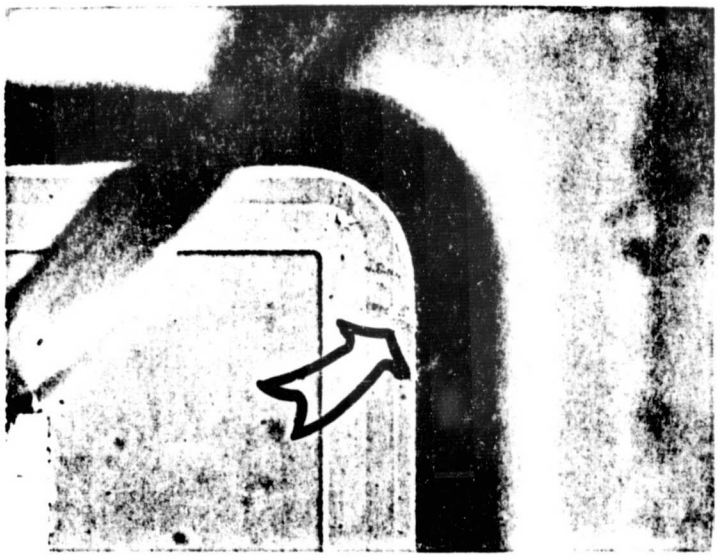

FIGURE A-3
S/N 4476. MAGNIFICATION 400X.
Arrow indicates extraneous spot of
metallization on channel-stopper diffusion.